

## OC Test / SC Test

$$S^2 = P^2 + Q^2$$

$$S = VI^*$$

$$Q = \sqrt{S^2 - P^2}$$

$$\text{OC: } X_m = \frac{V^2}{Q}$$

$$R_m = \frac{V^2}{P}$$

$$\text{SC: } X_{eq} = \frac{Q}{I^2}$$

$$R_{eq} = \frac{P}{I^2}$$

$$pf = \cos(\theta_{sc}) = \frac{P_{sc}}{V_{sc} I_{sc}} = \frac{P}{S}$$

$$\text{core loss} = P_{oc} = P_e \leftarrow \dots$$

$$\text{copper loss} = P_{sc} = P_{cu} = I^2 R_{eq}$$

$$\text{Max power at } P_c = P_{cu} \dots$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{S \cdot pf}{S \cdot pf + P_c + P_{cu}}$$

$$VR = \frac{V_1 - V_2'}{V_2'}$$

$$\eta = \frac{n \cdot S \cdot pf}{n \cdot S \cdot pf + n^2 P_{cuFL} + P_{core}}$$

$$n = \text{load } (0 \rightarrow 1)$$

## PV

$$P_{base} = Q_{base} = V_{base} I_{base}$$

$$Z_{base} = \frac{V_{base}^2}{V_{base} I_{base}}$$

$$I_{base} = \frac{V_{base}}{Z_{base}}$$

$$X_{new} = X_{old} \left( \frac{MVA_{new}}{MVA_{old}} \right)^2$$

$$E_a = K_a \phi \omega_m$$

$$T_e = K_a \phi I_a$$

$$P_{em} = E_a I_a = T_e \omega_m$$

$$\omega_m = \frac{V_t - I_a R_a}{K_a \phi}$$

$$T_e = \frac{E_a I_a}{\omega_m}$$

$$T_e = K I_a^2$$

$$V_t - I_a R_a = K I_a \omega_m$$

$$V_t = I_a (K \omega_m + R_a)$$

## DC

$$I_f$$

$$R_f$$

$$E_a$$

$$V_f = I_f R_f$$

$$V_t = E_a \pm I_a R_a$$

$$(Motor/Gen)$$

$$V_f = I_f R_f$$

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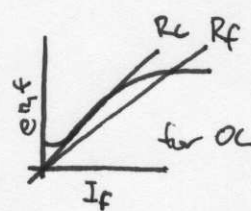
$$(Motor/Gen)$$



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$$V_f = I_f R_f, \quad V_t = E_a \pm I_a R_a \quad (\text{Motor/Gen})$$



Starting:  $\rightarrow$  find  $E_a$  for FL

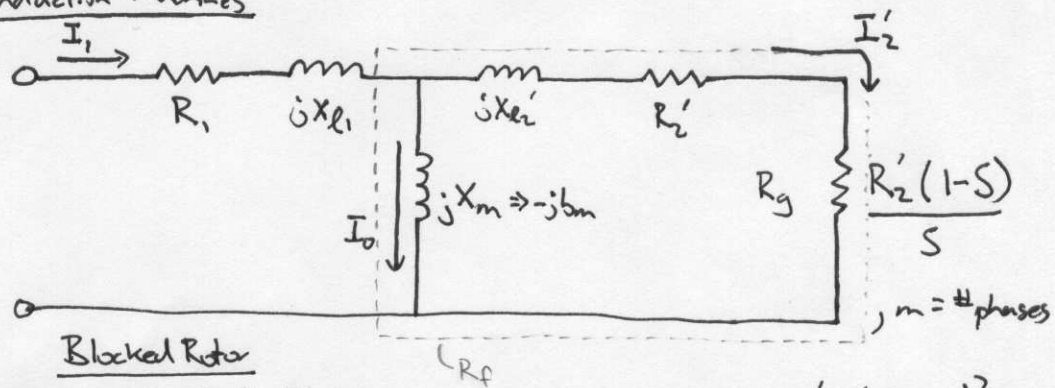
$\rightarrow$  find  $K_a \phi$  for FL

$$\rightarrow I = \frac{V_t - E_{a,FL}}{R_a + R_{starting}}$$

$$\rightarrow E_a = V_t - (R_a + R_{starting}) I \quad (\text{Subst out } I)$$

$\rightarrow$  find new  $\omega_m$

## Induction Machines



## Blocked Rotor

$$R_{eq} = R_1 + R_2' = P_s / I_s^2$$

$$Z_{eq} = V_s / I_s$$

$$X_{eq} = X_{l1} + X_{l2}' = \sqrt{Z_{eq}^2 - R_{eq}^2}$$

$$\text{Blocked } pf = \cos \phi_s = P_s / V_s I_s$$

$$\text{given } V_L, I_L, P_{3\phi}$$

$$\rightarrow V_s, I_s, P_s$$

$$R_2' = \frac{(R_{eq} - R_1)(X_{l2}' + X_m)^2}{X_m^2}$$

$$X_{l1} = X_{l2}' = X_{eq} / 2$$

$$X_m = X_0 - X_{l1}$$

for motor,  $S = 0 \rightarrow 1$   
gen,  $S = 1 \rightarrow$

## No-load

$$R_0 = R_1 + R_m = P_0 / I_0^2$$

$$Z_0 = V_0 / I_0$$

$$X_0 = X_{l1} + X_m = \sqrt{Z_0^2 - R_0^2}$$

$$\text{No-load } pf = \cos \phi_0 = P_0 / V_0 I_0$$

$$\text{given } V_L, I_L, P_{3\phi}$$

$$\rightarrow V_0, I_0, P_0$$

$$\text{get } \rightarrow Z_0, R_0, X_0, R_m$$

$R_f = \text{everything in } \square$

$$Z_t = R_1 + jX_{L1} + R_f, \quad \phi = \text{pf}$$

$$I_1 = V_{in} \phi / Z_t$$

$$P_g = m (I_2')^2 \frac{R_2'}{s} = m I_1^2 R_f$$

$$P_m = P_g (1-s)$$

$$P_{rot} = m \left[ P_{in} \phi - \underbrace{I_1^2 R_1}_{\text{stator copper loss}} \right]$$

$$P_{out} = P_m - P_{rot}$$

$$P_{out} = T_{out} \omega_m, \quad \omega_m = \omega_s (1-s)$$

$$T_{out} = \frac{P_{out}}{\omega_s (1-s)}, \quad \omega_s = \frac{2\pi f}{\# \text{poles}/2}, \quad T_{out} = \frac{I_2'^2 R_2'}{s \omega_s}, \quad \text{slip at start} = 1$$

$$P_{in} = \sqrt{3} |V_L| |I_L| (\text{pf})$$

$$V_{1a} = V_1 - I_o (R_1 + jX_{L1}) = V_1 \frac{jX_m}{R_1 + j(X_{L1} + X_m)}$$

$$R_1'' + jX_1'' = \frac{(R_1 + jX_{L1}) jX_m}{R_1 + j(X_{L1} + X_m)}$$

$$S_{maxT} = \frac{R_2'}{\sqrt{(R_1'')^2 + (X_1'' + X_{L2}')^2}}$$

$$T_{max} = \frac{1}{\omega_s} \frac{(0.5) m (V_{1a})^2}{\sqrt{(R_1'')^2 + (X_1'' + X_{L2}')^2}}$$

$$\frac{T}{T_{max}} = \frac{2}{(s/S_{maxT}) + (S_{maxT}/s)}$$

$$E_{rms} = 4.44 f N \phi, \quad \phi \propto \text{const?}, \quad E_{rms} \propto f$$

$$\text{slip speed} = \omega_s - \omega_m = s \omega_s$$

Shunt motor  
Shunt generator

$$\eta_m = 1 - \frac{V_t (I_f + I_a) + I_a^2 R_a}{V_t (I_f + I_a)}$$

shunt gen

$$\eta_g = 1 - \frac{V_t (I_f + I_a) + I_a^2 R_a}{V_t (I_f + I_a) + I_a^2 R_g}$$

Kapp-Hopkins

$$\text{generator input} = \text{motor output} = \eta (\text{motor input}) = \eta (V_t I_a)$$

$$\text{generator output} = V I_B = \eta (\text{gen. input}) = \eta^2 V I_a$$

$$\eta = \sqrt{I_B / I_a}$$

$$P = V I_L - (I_a^2 R_{a1} - I_B^2 R_B)$$

$$\eta_m = 1 - \frac{P/2 + I_a^2 R_{a1} + V I_a}{V (I_a + I_{a1})}$$

$$\eta_g = 1 - \frac{P/2 + I_B^2 R_B + V I_{B1}}{V (I_B - I_{B1}) + P/2 + I_B^2 R_B}$$

$$I_2' \propto V_1$$

$$\frac{I_2' \text{ reduced voltage}}{I_2' \text{ full-load voltage at starting}} = k$$

$$I_2' \text{ full-load voltage at starting}$$

$$\therefore I_2' \text{ red voltage} = k (I_2')_{FL} \text{ voltage at starting}$$

$$V_{X1/2} = V_{Y1/2} \frac{X_{M1/2}}{Y_{1/2}}$$